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INFLUENCE OF GRANULATION ON CHEMICAL COMPOSITION AND BAKING QUALITY OF FLOUR[1]

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PREVIOUS INVESTIGATIONS

Degree of fineness and uniformity in size of the flour particles are of importance to baking quality and of considerable interest to the milling trade and to milling and baking experimenters. This interest has many different sides and is evidenced in a variety of ways. To the milling trade, consideration of these factors is necessary in order to produce flour of the maximum baking quality from any given lot of wheat; to the milling and baking experimenter, such information is essential to the study of the quality of different wheats in order that he may properly interpret his results. Furthermore,

[1] Credit is due James F. Hayes for his assistance in the milling of the material used in this investigation, to H. B. Dixon and H. C. Fellows for their assistance in making the chemical determinations, and to W. K. Marshall and Ray Weaver for making the baking tests.

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this left-over material was added to the part that passed through and the whole sample was thoroughly mixed. The mixing was done with extreme care to insure that the different types or qualities of granulates, of which, no doubt, each sample was composed, would be equally distributed throughout the whole sample. This method constituted a form of excessive grinding a little different from that in method 1, but was for the same purpose.

(3) The third method of treatment used was that employed by LeClerc and his coworkers, and was applied to both the coarse middlings stocks and the flours. The middlings, because of their relative coarseness, were ground once on the smooth rolls, and in one case twice before being sifted. This method consisted of the grading or sifting out of the particles of various sizes by the use of sieves clothed with 8xx, 10xx, 12xx, 16xx, 20xx, and 25xx, silk bolting cloth. The purpose of this method was to determine the difference in baking quality and chemical composition between different sized particles of which flour is normally composed.

OUTLINE OF CHEMICAL STUDIES

Each sample resulting from these investigations was subjected to the usual flour analyses. The methods used are those described in the official and tentative methods of analysis of the Association of Official Agricultural Chemists unless otherwise noted. In addition, special attention was given to the quality of the gluten in the excessively ground samples, as well as to the quantity and quality of the gluten in the different-sized flour particles sifted from the various flours and middlings stocks.

The effect of excessive grinding upon the starch particles was also studied. The diastatic activity of some of the excessively ground flours was determined, as was that of some of the different-sized particles of which flour is normally composed. The diastatic determinations were also compared with the quantity of total material extracted by cold water, as material of this sort was shown by Alsberg and Griffing to be composed largely of dispersed starch.

The data showing the chemical composition of the two series of flour samples excessively ground in the way previously described as methods 1 and 2, are given in Tables 1 and 2. The chemical composition of flour particles, or granulates, of varying degree of fineness, of which middlings stocks ground to a normal degree of fineness and commercial flours are composed, is given in Table 3.

TABLE 1.—*Chemical composition of middlings stock and commercial flours ground various numbers of times*

Kind of material used	Condition of material used	Moisture	Results on basis of 13.5 per cent moisture				
			Ash	Protein	Titratable acidity as lactic acid	pH	Gasoline color value
		Per cent	*Per cent*	*Per cent*	*Per cent*		
Soft red winter coarse middlings stock No. 12550.	Original material	13.26	0.379	9.96	0.167	5.93	0.90
	Ground once	13.12	.383	9.97	.156	5.89	.93
	Ground 4 times	12.64	.381	9.76	.156	5.88	.89
	Ground 10 times	12.22	.375	9.81	.152	5.85	.88
	Ground 20 times	11.30	.380	9.91	.154	5.83	.90
Soft red winter coarse middlings stock No. 12551.	Original material	13.96	.352	10.84	.142	6.14	.88
	Ground once	13.52	.351	10.86	.147	6.17	.87
	Ground 4 times	13.41	.355	10.81	.147	5.89	.93
	Ground 10 times	12.75	.359	10.80	.141	6.11	.90
	Ground 20 times	12.93	.356	10.72	.135	6.00	.88
Hard wheat coarse middlings stock No. 12621.	Original material	14.31	.525	10.29	.138	6.36	.93
	Ground once	13.89	.412	10.45	.128	6.35	1.15
	Ground 4 times	13.22	.409	10.55	.127	6.24	1.30
	Ground 10 times	12.74	.422	10.64	.125	6.25	1.27
	Ground 20 times	12.66	.406	10.52	.130	6.27	1.31
Soft red winter straight flour No. 12552.	Original material	12.93	.360	9.94	.135	6.10	.86
	Ground once	13.13	.375	10.02	.142	6.22	.87
	Ground 4 times	13.12	.375	9.96	.142	6.25	.93
	Ground 10 times	12.76	.383	9.92	.137	6.21	.83
	Ground 20 times	12.05	.381	9.92	.136	6.02	.86
Hard wheat patent flour No. 12620.	Original material	13.47	.455	10.45	.142	6.22	.92
	Ground once	13.47	.450	10.45	.137	6.28	.95
	Ground 4 times	13.15	.443	10.45	.131	6.33	.97
	Ground 10 times	12.87	.438	10.43	.137	6.28	1.00
	Ground 20 times	12.33	.440	10.45	.137	6.25	1.24
Hard wheat first clear flour No. 12618.	Original material	12.84	.794	11.73	.302	6.32	1.35
	Ground once	12.75	.789	11.75	.300	6.35	1.17
	Ground 4 times	12.58	.796	11.72	.296	6.31	1.30
	Ground 10 times	12.12	.798	11.89	.295	6.29	1.45
	Ground 20 times	11.74	.794	11.75	.300	6.27	1.55
Hard wheat second clear flour No. 12619.	Original material	12.31	1.716	12.63	.580	6.23	1.51
	Ground once	12.19	1.724	12.64	.550	6.29	1.65
	Ground 4 times	11.97	1.720	12.62	.550	6.29	1.68
	Ground 10 times	11.54	1.726	12.63	.545	6.28	1.88
	Ground 20 times	11.04	1.702	12.85	.540	6.19	1.88

TABLE 2.—*Chemical composition of middlings stock ground to different degrees of fineness*

Kind of material used	Condition of material used	Moisture	Results on basis of 13.5 per cent moisture				
			Ash	Protein	Titratable acidity as lactic acid	pH	Gasoline color value
		Per cent	*Per cent*	*Per cent*	*Per cent*		
Soft red winter wheat coarse middlings stock No. 12550.	Original material	13.26	0.379	9.96	0.167	5.93	0.90
	Ground to pass through 12xx	13.12	.379	9.84	.155	5.93	.92
	Ground to pass through 16xx	12.82	.377	9.81	.156	5.91	.93
	Ground to pass through 20xx	12.78	.356	9.80	.157	5.86	.93
	Ground to pass through 25xx	12.47	.370	9.80	.156	5.87	.93
Soft red winter wheat coarse middlings stock No. 12551.	Original material	13.96	.352	10.84	.142	6.14	.88
	Ground to pass through 12xx	13.58	.353	10.84	.141	6.15	.88
	Ground to pass through 16xx	13.01	.375	10.73	.140	6.18	.95
	Ground to pass through 20xx	13.56	.350	10.79	.140	6.12	.96
	Ground to pass through 25xx	13.31	.351	10.91	.147	6.10	.84
Hard wheat coarse middlings stock No. 12621.	Original material	14.31	.525	10.29	.138	6.36	.93
	Ground to pass through 12xx	13.04	.413	10.37	.125	6.28	1.26
	Ground to pass through 16xx	12.38	.405	10.45	.124	6.27	1.30
	Ground to pass through 20xx	12.44	.400	10.55	.126	6.25	1.38
	Ground to pass through 25xx	11.99	.410	10.56	.126	6.25	1.17

TABLE 3.—*Chemical composition of the various sized particles of flour*

Kind of material used	Condition of material used	Proportion of whole	Moisture in flour	Results on basis of 13.5 per cent moisture				
				Ash	Protein	Titratable acidity as lactic acid	pH	Gasoline color value
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*		
Soft red winter wheat coarse middlings, stock No. 12550	Original material	-------	13.26	0.379	9.96	0.167	5.93	0.90
	Same material ground twice and then sifted:							
	Scalpings from 8xx	0.4	12.89	1.331	8.86	-------	-------	1.14
	Scalpings from 12xx through 8xx.	20.4	12.89	.482	11.01	.189	6.01	1.04
	Scalpings from 16xx through 12xx.	15.4	12.83	.333	11.15	.161	5.78	1.03
	Scalpings from 20xx through 16xx.	8.5	12.89	.303	11.09	.151	5.78	1.03
	Scalpings from 25xx through 20xx.	17.3	12.82	.312	10.58	.147	5.84	1.07
	Throughs from 25xx	38.0	12.78	.298	7.93	.147	5.86	.84
Soft red winter wheat coarse middlings, stock No. 12551.	Original material	-------	13.96	.352	10.84	.142	6.14	.88
	Same material ground once and then sifted:							
	Scalpings from 8xx	.9	13.75	.890	13.01	.336	6.25	1.08
	Scalpings from 12xx through 8xx.	39.4	13.79	.390	11.33	.147	6.03	.86
	Scalpings from 16xx through 12xx.	30.7	13.70	.375	11.14	.126	5.97	.94
	Scalpings from 20xx through 16xx.	9.3	13.84	.360	11.28	.142	6.15	.92
	Scalpings from 25xx through 20xx.	9.2	13.93	.380	9.86	.142	6.17	.88
	Throughs from 25xx	10.5	13.95	.330	7.98	.116	6.17	.71
Hard wheat coarse middlings, stock No. 12621.	Original material	-------	14.31	.525	10.29	.138	6.36	.93
	Same material ground once and then sifted:							
	Scalpings from 8xx	10.4	13.46	.925	10.93	.294	6.35	1.14
	Scalpings from 12xx through 8xx.	36.3	13.54	.360	10.46	.105	6.25	1.10
	Scalpings from 16xx through 12xx.	21.1	13.57	.350	10.55	.105	6.25	1.08
	Scalpings from 20xx through 16xx.	10.3	13.68	.350	10.67	.100	6.23	1.15
	Scalpings from 25xx through 20xx.	13.3	13.80	.365	11.00	.110	6.23	1.13
	Throughs from 25xx	8.6	13.61	.405	8.69	.110	6.30	1.26
Soft red winter wheat straight flour, No. 12552.	Original material	-------	12.93	.360	9.94	.135	6.10	.86
	Scalpings from 12xx	10.7	13.15	.400	11.45	.137	6.33	.91
	Scalpings from 16xx through 12xx.	58.1	13.21	.385	11.07	.151	6.29	.98
	Scalpings from 20xx through 16xx.	6.4	13.38	.375	10.38	.158	6.12	.86
	Scalpings from 25xx through 20xx.	7.9	13.09	.380	9.30	.146	6.18	.82
	Throughs from 25xx	16.9	13.27	.360	7.54	.116	6.21	.71
Hardwheat patent flour, No. 12620.	Original material	-------	13.47	.455	10.45	.142	6.22	.92
	Scalpings from 12xx	14.0	13.33	.395	10.78	.124	6.30	1.00
	Scalpings from 16xx through 12xx.	49.6	13.30	.415	11.39	.136	6.22	1.15
	Scalpings from 20xx through 16xx.	9.0	13.10	.480	10.85	.158	-------	.98
	Scalpings from 25xx through 20xx.	7.0	12.92	.510	10.85	.166	6.25	1.02
	Throughs from 25xx	20.4	12.73	.501	8.82	.166	6.23	.88
Hard wheat first clear flour, No. 12618.	Original material	-------	12.84	.794	11.73	.302	6.32	1.35
	Scalpings from 12xx through 8xx.	15.6	12.57	.698	11.19	.255	6.30	1.21
	Scalpings from 16xx through 12xx.	20.5	12.58	.658	11.63	.255	6.32	1.72
	Scalpings from 20xx through 16xx.	15.2	12.65	.773	12.99	.285	6.33	1.39
	Scalpings from 25xx through 20xx.	14.3	12.18	.822	12.98	.305	6.27	1.33
	Throughs from 25xx	34.4	12.46	.939	10.53	.310	6.32	1.21
Hard wheat second clear flour, No. 12619.	Original material	-------	12.31	1.716	12.63	.580	6.23	1.51
	Scalpings from 12xx through 8xx.	9.7	12.07	1.519	12.59	.525	6.25	1.77
	Scalpings from 16xx through 12xx.	60.2	11.92	1.670	13.14	.560	6.25	1.65
	Scalpings from 20xx through 16xx.	6.7	11.90	1.822	13.34	.585	6.25	1.83
	Scalpings from 25xx through 20xx.	10.4	11.83	1.903	12.17	.590	6.23	1.67
	Throughs from 25xx	13.0	11.82	1.903	11.48	.590	6.22	1.67

EFFECT OF EXCESSIVE GRINDING UPON THE CHEMICAL COMPOSITION OF FLOUR

Referring to Tables 1 and 2, it will be found from a quantitative standpoint that excessive grinding did not greatly affect the usual factors sought after in the chemical analysis of flour.

As would be expected from excessive grinding, there was a reduction in the moisture content of the sample, the greatest change with but three exceptions being associated with the greatest amount of grinding. The percentage of ash and crude protein was not influenced. Color pigments extractable in gasoline were obtained in larger quantities on the average from those samples that were much overground. Although the change in the hydrogen-ion concentration was not great, there was a fairly definite tendency for it to increase with the increasing fineness of division of the flour particle. No appreciable change in titratable acidity was noticeable. The method followed for making the hydrogen-ion determination was that described by Johnson [6] and Bailey.

CHEMICAL COMPOSITION OF THE DIFFERENT-SIZED PARTICLES OF WHICH FLOUR IS NORMALLY COMPOSED

The chemical composition of flour particles or granulates of varying degrees of fineness sifted from middlings stocks ground to a normal degree of fineness and commercial flours is given in Table 3. It will be seen that the moisture content of these separates did not vary greatly. Neither was there any very noticeable tendency for this factor to increase or decrease as the fineness of particle increased.

The ash content of the various flour separates from most of the materials was variable and was different in tendency of direction for each of the two classes of wheat studied. The ash content of the flour separates resulting from the ground soft red winter wheat middlings stocks was in most instances progressively lower as the flour particle decreased in size. The reverse of this was true for the different-sized particles sieved from the ground hard wheat middlings stock and from the hard wheat patent, first, and second clear flours. In the case of these latter separates the material passing through the 20xx and 25xx silk cloths contained the largest quantities of ash of any of the separates. The data in regard to the hard wheat materials seem to be in accord with the data submitted earlier by LeClerc and his coworkers from their studies with commercial hard wheat flours. Whether the difference in tendency shown between the two classes of wheat in regard to ash content is due to differences in the nature of these wheats, or is the result of milling conditions, is not known and is a point under investigation.

The protein content of the particles of flour that passed through the 25xx sieve was significantly less than the protein content of those flours which passed through the 8xx, 12xx, or 16xx sieves. On the other hand, with but two exceptions, there was not a great deal of difference in the protein content of the flour passing through the 8xx, 12xx, and 16xx sieves.

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[6] JOHNSON, ARNOLD C., and BAILEY, C. H. A PHYSIO-CHEMICAL STUDY OF CRACKER DOUGH FERMENTATION. Cereal Chem., vol. 1, No. 7, p. 329. 1924.

The titratable acidities of the patent and first and second clear flours made from the hard wheat paralleled their ash content. The coarsest portion showed the least acidity, with a gradual increase in acidity as the granulates became finer in size. No great difference was apparent in the titratable acidity of the various separates obtained by sieving the flour milled from the hard wheat coarse middlings stock sample No.12621, all of the flours passing through 12, 16, 20, and 25xx sieves having practically the same degree of acidity. With the siftings from the soft red winter coarse middlings stock sample No. 12550 there was a parallelism between the ash content, titratable acidity, and the fineness of division of the sample. The acidity of the different-sized flour particles obtained from samples Nos. 12551 and 12552 was irregular, and did not follow the size of the particle or the ash content.

The hydrogen-ion content of the flour particles of different sizes was not appreciably different, as a difference of three-tenths in pH value would more than cover the change from one extreme in flour particle size to the other.

The finest flour particles according to the gasoline color test were whitest in color. This fact seemed to be true with but one exception, namely, sample No. 12621.

INFLUENCE OF EXCESSIVE GRINDING UPON THE QUANTITY AND QUALITY OF THE GLUTEN IN FLOUR

Extensive tests were made of the influence of excessive grinding upon the quantity and quality of the gluten proteins of the flour. Information was sought concerning the effect of excessive grinding upon the quantity of crude protein, the percentage of wet and dry gluten, the imbibitional qualities of the gluten proteins, the percentage of nitrogen soluble in cold water, and the influence upon the water imbibing constituent of the gluten protein, glutenin.

The imbibitional qualities of the gluten proteins were studied by two methods. The percentage of wet and dry gluten in the samples washed with tap water were determined, and, from these data, the water absorbed or imbibed per gram of dry gluten was ascertained. Later the hydration capacity of the gluten protein was determined by noting for each of the treated flours the viscosity of flour and water suspensions containing the equivalent of 2 grams of protein. The viscosity determinations were made on a MacMicheal viscosimeter. The test material was washed with 150 cubic centimeters of distilled water, and the readings made with a 2-centimeters bob, with the cup of the viscosimeter rotating at 76 revolutions per minute.

Glutenin determinations were made according to the method of Blish.[7] Cold water soluble extract was determined by the methods of the Association of Official Agricultural Chemists.[8] The data resulting from this phase of the investigation are shown in Tables 4 and 5. The data in Table 4 relate to those samples of flour ground from 1 to 20 times, whereas the figures in Table 5 are from those flour samples ground to different degrees of fineness.

[7] Blish, M. J., and Sandstedt, R. M. GLUTENIN—A SIMPLE METHOD FOR ITS PREPARATION AND DIRECT QUANTATIVE DETERMINATION. Cereal Chem. vol. 2, No. 2, p. 57.

[8] Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. Revised to July 1, 1924, p. 227, par. 14.

TABLE 4.—*Quantity and quality of the gluten proteins in middlings stock and commercial flours ground various numbers of times*

Kind of material used	Condition of material used	Results on basis of 13.5 per cent moisture							
		Protein in flour	Dry gluten	Wet gluten	Water absorbed per gram of dry gluten	Protein in dry gluten	Viscosity °M[1]	Glutenin in total protein	Cold water soluble nitrogen in total nitrogen
		Per cent	*Per cent*	*Per cent*	*Grams*	*Per cent*		*Per cent*	*Per cent*
Soft red winter wheat coarse middlings stock, No. 12550.	Original material	9.96	9.17	25.33	2.76	-------	146	-------	-------
	Ground once	9.97	9.58	27.50	2.87	-------	196	36.31	-------
	Ground 4 times	9.76	9.37	26.68	2.85	-------	186	36.10	-------
	Ground 10 times	9.81	8.77	25.10	2.86	-------	182	36.20	-------
	Ground 20 imes	9.91	8.85	25.19	2.85	-------	163	36.13	-------
Soft red winter wheat coarse middlings stock, No. 12551.	Original material	10.84	11.59	33.29	2.87	-------	126	41.05	17.33
	Ground once	10.86	11.19	31.97	2.86	-------	155	40.79	17.34
	Ground 4 times	10.81	10.62	30.53	2.87	-------	162	40.43	16.95
	Ground 10 times	10.80	10.46	29.80	2.85	-------	161	40.39	17.78
	Ground 20 times	10.72	10.12	28.93	2.86	-------	156	41.04	18.28
Hard wheat coarse middlings stock, No. 12621.	Original material	10.29	10.54	26.63	2.53	75.01	59	41.04	-------
	Ground once	10.45	10.47	27.91	2.67	79.48	144	41.56	-------
	Ground 4 times	10.55	10.59	27.11	2.56	81.06	160	41.50	-------
	Ground 10 times	10.64	10.49	27.70	2.64	80.05	160	41.45	-------
	Ground 20 times	10.52	10.24	27.16	2.65	81.67	163	41.29	-------
Soft red winter wheat straight flour, No. 12552.	Original material	9.94	10.04	27.85	2.77	78.91	152	36.42	-------
	Ground once	10.02	9.54	27.37	2.87	82.82	149	36.63	20.36
	Ground 4 times	9.96	9.92	27.70	2.79	81.55	148	36.14	19.28
	Ground 10 times	9.92	9.72	27.10	2.79	82.23	147	36.49	19.15
	Ground 20 times	9.92	9.47	26.84	2.83	79.71	150	36.59	17.04
Hard wheat patent flour, No. 12620.	Original material	10.45	10.76	26.93	2.50	77.24	155	41.44	12.34
	Ground once	10.45	10.73	26.37	2.46	78.58	162	41.72	12.34
	Ground 4 times	10.45	10.77	26.75	2.48	78.37	167	41.69	12.78
	Ground 10 times	10.43	10.57	26.11	2.47	78.43	162	41.55	13.33
	Ground 20 times	10.45	10.57	25.54	2.42	78.82	162	41.59	12.44
Hard wheat first clear flour, No. 12618.	Original material	11.73	12.65	29.31	2.32	71.93	120	46.63	12.62
	Ground once	11.75	12.83	30.61	2.39	72.64	121	46.55	12.00
	Ground 4 times	11.72	12.47	29.74	2.39	74.65	129	46.76	12.07
	Ground 10 times	11.89	12.43	29.55	2.38	-------	126	46.58	-------
	Ground 20 times	11.75	12.75	29.88	2.34	74.54	127	46.65	12.17

[1] Degrees MacMicheal.

Considering first the data given in Table 4 relative to the influence of a various number of grindings upon the quality and quantity of the washed gluten, it was found that excessive grinding of the two samples of the soft red winter wheat middlings stocks resulted in a gradual decrease in the quantity of wet and dry gluten. The greatest reductions occurred in the samples that had been ground ten and twenty times and amounted to about 10 per cent. No great change in the gluten proteins seems to have taken place previous to grinding at least ten times.

Excessive grinding apparently did not injure the gluten in the hard wheat middlings stock, as no noticeable decrease in quantity or quality of gluten was experienced. This was likewise true for the tests made on the hard wheat first clear flour. Excessive grinding did not injure the washed gluten in the hard wheat patent flour or in the straight grade soft red winter wheat flour until the sample had been ground at least twenty times.

TABLE 5.—*Quantity and quality of the gluten proteins in middlings stock ground to different degrees of fineness*

Kind of material used	Condition of material used	Results on basis of 13.5 per cent moisture							
		Protein in flour	Dry gluten	Wet gluten	Water absorbed per gram of dry gluten	Protein in dry gluten	Viscosity °M[1]	Glutenin in total protein	Cold water soluble nitrogen in total nitrogen
		Per cent	*Per cent*	*Per cent*	*Grams*	*Per cent*		*Per cent*	*Per cent*
Soft red winter wheat coarse middlings stock No. 12550.	Original material	9.96	9.17	25.33	2.76	81.46	146	------	------
	Ground to pass through 12xx.	9.84	9.08	24.81	2.73	82.56	170	35.87	------
	Ground to pass through 16xx.	9.81	8.94	25.11	2.81	82.90	165	35.98	------
	Ground to pass through 20xx.	9.80	9.19	26.84	2.92	83.70	161	36.08	------
	Ground to pass through 25xx.	9.80	9.15	26.93	2.94	80.22	159	36.02	------
Soft red winter wheat coarse middlings stock No. 12551.	Original material	10.84	11.59	33.29	2.87	------	126	41.05	17.33
	Ground to pass through 12xx.	10.84	10.75	31.44	2.92	------	174	40.41	17.27
	Ground to pass through 16xx.	10.73	10.56	30.49	2.89	------	173	40.35	17.43
	Ground to pass through 20xx.	10.79	10.75	30.78	2.86	------	168	40.41	17.42
	Ground to pass through 25xx.	10.91	10.79	31.00	2.87	------	155	40.45	17.05
Hard wheat coarse middlings stock No. 12621.	Original material	10.29	10.54	26.63	2.53	75.01	59	41.04	20.36
	Ground to pass through 12xx.	10.37	10.61	28.45	2.68	76.74	170	41.56	20.36
	Ground to pass through 16xx.	10.56	10.72	28.37	2.65	79.53	171	41.30	19.28
	Ground to pass through 20xx.	10.46	10.63	28.63	2.69	79.19	174	41.39	19.15
	Ground to pass through 25xx.	10.52	10.47	28.25	2.70	79.24	174	41.05	17.04

[1] Degrees MacMicheal.

The viscosity measurements for gluten quality bear out, in a general way, the findings obtained by the washed-gluten test on all classes of material. The glutenin content of the flour samples was not altered to any very noticeable extent by excessive grinding. The changes in the imbibitional qualities of the gluten proteins noted above, therefore, must be explained by some physical alteration in the glutenin present rather than by a loss of any of this constituent as a result of excessive grinding.

Contrary to the findings of Alsberg and Griffing, it can not be said from the investigations made here, that excessive grinding reduced the percentage of water-soluble nitrogen in the flour except in the case of the soft red winter wheat straight flour. Likewise, in only one or two instances did it appear that excessive grinding resulted in a condition which increased the protein content of the gluten proteins.

In Table 5 are presented data pertaining to the quantity and quality of the gluten proteins resulting from the second series of tests in which the excessive grinding was accomplished by grinding to a definite degree of fineness. These data are similar in nature to those collected from the grinding of the samples a definite number of times, in that the washed gluten tests did not indicate any great

injury to the gluten proteins from excessive grinding, and in that the viscosity tests showed for the soft red winter wheat middlings a slightly progressive impairment of gluten quality and for the hard wheat middlings a slightly progressive improvement. As before, no loss of glutenin owing to excessive grinding was experienced, neither was the water-soluble nitrogen nor the percentage of total protein in the washed gluten greatly modified by the treatment the flour received.

The making of washed gluten tests on the excessively ground flours presented some difficulties. The most excessively ground samples required more water to wet the dough into a homogenous condition. Washing the gluten from these samples was exceedingly trying, inasmuch as the gluten particles were crumbly, lacked elasticity, and were difficult to assemble in one mass.

QUANTITY AND QUALITY OF THE GLUTEN PROTEIN IN THE DIFFERENT-SIZED PARTICLES OF WHICH FLOUR IS NORMALLY COMPOSED

In Table 6 are shown results of the study relative to the quantity and quality of the gluten in flour particles of different sizes sifted from commercial flours and from normally reduced middlings stocks.

The percentage of wet and dry gluten in the various separates paralleled the percentage of crude protein very closely, inasmuch as the finest particles contained the smallest percentage of both wet and dry gluten. If the quality of the gluten is judged from the standpoint of water absorbed per gram of dry gluten, the quality factor seems to have been fairly constant for all sizes of particles.

When the viscosity test is applied to equal concentrations of the flour protein, however, the results show fairly conclusively that the smaller sized particles contained protein of inferior quality. There was some variation, depending upon the nature of the original material and the class of wheat from which it was obtained, as to which sized particle had the lowest gluten quality; but it is fairly safe to state that the particles passing through the 20xx and 25xx sieves as a rule contained protein of a quality inferior to that found in particles passing through the 12xx and 16xx sieves. The material which passed through the 8xx sieve also contained protein of an inferior quality.

Some interesting figures present themselves when the glutenin determinations on the various sized particles are considered. With the material sieved from the soft red winter wheat middlings stock, sample No. 12551, and from the straight grade of soft red winter wheat flour, sample No. 12552, there seemed to be a fairly consistent reduction in the quantity of glutenin as the size of the flour particle decreased. This also was definitely the case with the smaller-sized particles sieved from the material represented by samples Nos. 12550, 12621, and 12620. With the hard wheat first clear flour, the glutenin content was found to increase as the size of the flour particles decreased.

The viscosity measurements, with the exception of those made on the separates obtained from sample No. 12,618, to a large extent paralleled the glutenin determinations.

TABLE 6.—*Quantity and quality of the gluten proteins in the various-sized particles of which flour is normally composed*

Kind of material used	Condition of material used	Results on basis of 13.5 per cent moisture							
		Protein in flour	Dry gluten	Wet gluten	Water absorbed per gram of dry gluten	Protein in dry gluten	Viscosity °M[1]	Glutenin in total protein	Cold water soluble nitrogen in total nitrogen
		Per cent	*Per cent*	*Per cent*	*Grams*	*Per cent*		*Per cent*	*Per cent*
Soft red winter wheat coarse middlings stock No. 12550.	Original material	9.96	9.17	25.33	2.76	.....	146	.....	.....
	Same material ground twice and then sifted:								
	Scalpings from 8xx	8.86	.....	.....	.....	.....	.....	.....	.....
	Scalpings from 12xx through 8xx.	11.01	11.00	31.91	2.90	.....	163	39.07	.....
	Scalpings from 16xx through 12xx.	11.15	10.97	30.76	2.80	.....	187	38.18	.....
	Scalpings from 20xx through 16xx.	11.09	11.22	30.31	2.70	.....	205	38.87	.....
	Scalpings from 25xx through 20xx.	10.58	9.81	27.96	2.85	.....	193	38.18	.....
	Throughs from 25xx	7.93	7.01	20.20	2.88	.....	168	35.56	.....
Soft red winter wheat coarse middlings stock No. 12551.	Original material	10.84	11.59	33.29	2.87	.....	126	41.05	17.33
	Same material ground once and then sifted:								
	Scalpings from 8xx	13.01	10.94	31.09	2.84	.....	95	32.67	16.06
	Scalpings from 12xx through 8xx.	11.33	11.14	32.47	2.91	.....	151	42.53	21.45
	Scalpings from 16xx through 12xx.	11.14	11.42	32.49	2.85	.....	175	38.24	21.81
	Scalpings from 20xx through 16xx.	11.28	11.14	32.15	2.89	.....	156	39.01	18.70
	Scalpings from 25xx through 20xx.	9.86	9.06	26.86	2.96	.....	132	37.53	17.95
	Throughs from 25xx	7.98	7.25	23.22	3.20	.....	142	33.33	19.30
Hard wheat coarse middlings stock No. 12621.	Original material	10.29	10.54	26.63	2.53	75.01	59	41.04	.....
	Same material ground once and then sifted:								
	Scalpings from 8xx	10.93	10.32	27.52	2.67	76.88	66	44.37	.....
	Scalpings from 12xx through 8xx.	10.46	10.71	28.45	2.66	79.79	164	38.11	.....
	Scalpings from 16xx through 12xx.	10.55	10.49	27.48	2.62	79.95	188	38.39	.....
	Scalpings from 20xx through 16xx.	10.67	10.65	27.92	2.62	80.93	180	38.61	.....
	Scalpings from 25xx through 20xx.	11.00	10.96	28.42	2.59	80.82	165	37.55	.....
	Throughs from 25xx	8.69	8.67	22.90	2.64	82.60	133	31.10	.....
Soft red winter wheat straight flour No. 12552.	Original material	9.94	10.04	27.85	2.77	78.91	152	36.42	.....
	Siftings:								
	Scalpings from 12xx	11.45	11.25	31.18	2.77	76.87	142	38.43	19.04
	Scalpings from 16xx through 12xx.	11.07	10.95	31.27	2.86	76.68	151	38.30	19.06
	Scalpings from 20xx through 16xx.	10.38	10.10	29.27	2.90	80.69	130	36.90	19.94
	Scalpings from 25xx through 20xx.	9.30	8.78	25.41	2.89	79.37	130	34.52	18.39
	Throughs from 25xx	7.54	7.13	20.22	2.84	81.75	124	32.23	20.29
Hard wheat patent flour No. 12620.	Original material	10.45	10.76	26.93	2.50	77.24	155	41.44	12.34
	Siftings:								
	Scalpings from 12xx	10.78	10.40	26.76	2.57	78.78	172	40.53	14.79
	Scalpings from 16xx through 12xx.	11.39	11.20	29.33	2.62	77.80	162	40.63	13.08
	Scalpings from 20xx through 16xx.	10.85	11.92	30.99	2.60	76.60	146	40.74	11.85
	Scalpings from 25xx through 20xx.	10.85	11.15	28.71	2.57	78.95	127	38.43	11.89
	Throughs from 25xx	8.82	8.82	21.78	2.47	80.58	128	36.96	12.81
Hard wheat first clear flour No. 12618.	Original material	11.73	12.65	29.31	2.32	71.93	120	46.63	12.62
	Siftings:								
	Scalpings from 12xx through 8xx.	11.19	12.50	30.17	2.41	71.46	127	44.77	12.87
	Scalpings from 16xx through 12xx.	11.63	12.72	30.95	2.43	72.50	139	44.44	12.47
	Scalpings from 20xx through 16xx.	12.99	14.78	34.73	2.35	71.76	123	44.88	12.09
	Scalpings from 25xx through 20xx.	12.98	14.07	32.41	2.30	72.38	113	46.30	11.48
	Throughs from 25xx	10.53	11.78	26.17	2.22	72.47	97	48.24	13.39

[1] Degrees MacMichael.

In one or two instances there was a tendency for the smaller sized particle to contain less nitrogen soluble in cold water. In this respect the results are of the same order as those found earlier by LeClerc and his coworkers and thus do not bear out the findings on this point advanced by Alsberg and Griffing.

INFLUENCE OF EXCESSIVE GRINDING ON THE STARCH PARTICLES

The mechanical injury to the starch particles caused by excessive grinding was studied in a manner similar to that described by Alsberg and Griffing. To determine the effect of excessive grinding upon the starch particles the total solids soluble in cold water and the diastatic power of the variously treated flours were studied. Cold-water extract was determined by the method of the Association of Official Agricultural Chemists previously mentioned. Diastatic power was determined by the method of Rumsey.[9]

The results are shown in Tables 7, 8, 9, and 10. Examination of Table 7, in which the cold-water extract of the flours ground 1 to 20 times is given, shows, as found earlier by Alsberg and Griffing, that the cold-water extract had a tendency to increase progressively with excessive grinding. The degree of injury found, was not so great as reported by Alsberg and Griffing, but was evident. On the other hand, the percentage of solids soluble in cold water did not seem to increase with the fineness of division of the normal flour particle, as the reverse of this was found in all four instances studied. (See Table 8.)

TABLE 7.—*Examination of cold-water extract of middlings stock and commercial flours ground various numbers of times*

Condition of material as used	Percentage of solid matter extracted by cold water				
	Sample No. 12551	Sample No. 12552	Sample No. 12620	Sample No. 12621	Sample No. 12618
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Ground once	4.32	4.20	5.07	4.59	5.74
Ground 4 times	4.35	4.22	5.28	4.50	5.88
Ground 10 times	4.39	4.34	5.47	4.42	----------
Ground 20 times	4.34	4.30	5.52	4.71	6.28

TABLE 8.—*Examination of cold-water extract of the various sized particles of which flour is normally composed*

Condition of material used	Percentage of solid matter extracted by cold water			
	Sample No. 12551	Sample No. 12552	Sample No. 12621	Sample No. 12618
	Per cent	*Per cent*	*Per cent*	*Per cent*
Scalpings from 8xx	4.53	----------	6.12	----------
Scalpings from 12xx through 8xx	4.89	4.85	4.41	6.04
Scalpings from 16xx through 12xx	4.96	4.42	4.45	5.67
Scalpings from 20xx through 16xx	4.90	4.32	4.43	5.75
Scalpings from 25xx through 20xx	4.35	3.97	4.28	5.64
Through 25xx	3.88	3.76	3.91	5.61

[9] RUMSEY, L. A. THE DIASTATIC ENZYMES OF WHEAT FLOUR AND THEIR RELATIONS TO FLOUR STRENGTH. Amer. Institute of Baking, Bul. 8. 1922.

TABLE 9.—*Diastatic activity of middlings stock and commercial flours ground various numbers of times*

Condition of material used	Weight of maltose from diastasis of 10 grams of flour				
	Sample No. 12551	Sample No. 12552	Sample No. 12620	Sample No. 12621	Sample No. 12618
	Grams	*Grams*	*Grams*	*Grams*	*Grams*
Ground once	0.0785	0.1085	0.3870	0.2340	0.3780
Ground 4 times	.0970	.1035	.3935	.2730	.3605
Ground 10 times	.1000	.1230	.4265	.3445	.4000
Ground 20 times	.1640	.1370	.4655	.3205	.4120

TABLE 10.—*Diastatic activity of the various sized particles of which flour is normally composed*

Condition of material used	Weight of maltose from diastasis of 10 grams of flour				
	Sample No. 12551	Sample No. 12552	Sample No. 12620	Sample No. 12621	Sample No. 12618
	Grams	*Grams*	*Grams*	*Grams*	*Grams*
Scalpings from 8xx	0.0665	----------	----------	0.3205	----------
Scalpings from 12xx through 8xx	.0890	0.0775	0.2305	.1805	0.2805
Scalpings from 16xx through 12xx	.0475	.0770	.2685	.1665	.2375
Scalpings from 20xx through 16xx	.0730	.0850	----------	.2220	.2775
Scalpings from 25xx through 20xx	----------	.1135	.4235	.2755	.3110
Through 25xx	.0870	.1305	.5090	.3270	.4260

INFLUENCE OF EXCESSIVE GRINDING ON DIASTATIC ACTIVITY

That excessive grinding materially increased the diastatic power of the resultant flours is evident from the data presented in Table 9. This was apparent in all the cases studied. The magnitude of this activity was variable, depending upon the class of the five flours studied. The greatest change was in the two soft red winter wheat flours Nos. 12551 and 12552.

It should be noted here that the diastatic power of the soft red winter wheat materials were very much lower than were those of the hard wheat materials.

INFLUENCE ON DIASTATIC ACTIVITY OF THE DIFFERENT-SIZED PARTICLES OF WHICH FLOUR IS NORMALLY COMPOSED

The diastatic activity of the different-sized particles of which flour is normally composed varied in tendency in some instances but was fairly consistent in that the flours which passed through the 16xx, 20xx, and 25xx sieves were noticeably greater in diastatic power than were those passing through the 8xx or 12xx sieves. (See Table 10.)

EFFECT OF EXCESSIVE GRINDING ON BAKING QUALITY

In the baking tests conducted on the various grindings and siftings of the three middlings stocks and the four commercial flours, two bakings were made on each. In some instances one baking was by the sponge-dough method and the second baking by the straight-dough method. In the other instances the sponge-dough method was used for both bakings.

The baking data obtained from the material resulting from grinding of middlings and commercial flours various numbers of times

are given in Table 11. This form of excessive grinding is described in a previous paragraph as method No. 1.

That the material underwent some physical change with each additional grinding there can be little doubt, because after these materials had been ground several times they became feathery or fluffy and greasy in character, which made them extremely difficult to feed into the rolls and to sift through the finer mesh sieves. This condition was more pronounced and became apparent after a fewer number of grindings for the soft red winter wheat middlings and straight flour and the hard wheat first and second clear flours than for the hard wheat middlings and patent flour.

Siftings were made of the materials resulting from the different grindings in an attempt to determine the relative fineness of each; and although the portions ground the most number of times were undoubtedly the finest, yet in many instances a smaller proportion of the material ground twenty times sifted through the 25xx silk cloth than of material which was ground ten times, four times, or even once. This result was probably due to the fact that the materials ground twenty times became feathery and greasy in character, which made them the more difficult to sift.

The results show for water absorption a very marked and consistent tendency for that factor to increase with each increase in the number of times ground.

The greatest loaf volumes were obtained usually from the materials ground once or four times and the smallest loaf volumes from those ground twenty times. The weight of loaf, as in the case of water absorption, increased with the number of grindings.

The only outstanding thing about the color of crumb scores was that the materials ground twenty times produced in nearly every instance the poorest scores, and in not a single instance the best score.

The best grain of crumb was obtained in a majority of the cases from the original material or from those portions ground once, and the poorest grain usually from those portions ground twenty times. Texture of crumb showed little or no tendency as to direction. In shade of color of crumb very little effect was noted, but wherever any difference was shown the lighter shadings were from the sample portions receiving the least grinding. In some of the materials tested a light grayness in the shade of color of crumb was apparent in the bread produced from those portions receiving the 20 grindings. The flours from which these breads were baked showed a very decided and consistent tendency to decrease in creaminess of color with the increase in the number of grindings. (See Table 11.)

Nothing very pronounced in the color and condition of the crust was noticeable.

The portions ground the most number of times required the longest proofing time and the original samples the shortest time, except in the cases of the hard wheat first and second clear flours, in which a reverse tendency was manifested. Another exception which probably should be noted here is the irregularity shown on the part of the hard-wheat patent-flour grindings baked by the straight-dough method.

TABLE 11.—*Baking results from middlings stock and*

Kind of material used	Condition of material used	Water absorption of flour	Volume of loaf	Weight of loaf	Color of crumb	Grain of crumb	Texture of crumb	Shade of color of crumb
RESULTS FROM SPONGE-DOUGH METHOD OF BAKING		*P. ct.*	*C. c.*	*Gms.*	*Score*	*Score*		
Soft red winter wheat coarse middlings stock No. 12550.	Original material	60.3	2,100	505	90.5	91.3	Very good	Light creamy
	Ground once	60.0	2,100	501	90.7	92.3	do	do
	Ground 4 times	60.0	2,110	501	90.8	92.2	Good	do
	Ground 10 times	61.5	2,110	506	90.8	92.0	do	Light creamy gray.
	Ground 20 times	62.9	2,020	510	90.0	89.0	do	do
Soft red winter wheat coarse middlings stock No. 12551.	Original material	59.7	2,090	497	93.0	91.8	Very good	Light creamy.
	Ground once	60.6	2,160	503	92.3	91.8	do	do
	Ground 4 times	60.6	2,050	499	92.1	91.5	do	do
	Ground 10 times	61.5	2,070	503	91.6	90.8	do	do
	Ground 20 times	64.7	2,030	510	91.2	88.5	do	do
Hard wheat coarse middlings stock No. 12621.	Original material	57.1	1,950	510	89.5	88.0	Fair, crumbly.	Creamy
	Ground once	57.1	1,930	507	88.5	86.5	Fair, solid, crumbly.	do
	Ground 4 times	60.9	1,850	509	87.0	85.5	Good, crumbly.	do
	Ground 10 times	62.1	1,910	511	88.0	86.0	Good	do
	Ground 20 times	62.4	1,910	513	87.5	85.0	do	do
Soft red winter wheat straight flour No. 12552.	Original material	56.5	2,140	492	93.5	91.5	Very good	Slightly creamy.
	Ground once	57.4	2,080	496	93.6	90.5	Good	Light creamy
	Ground 4 times	58.8	2,180	497	93.4	90.0	do	do
	Ground 10 times	60.0	2,100	497	93.3	89.0	do	do
	Ground 20 times	62.1	2,140	503	93.2	88.5	do	do
Hard wheat patent flour No. 12620.	Original material	60.0	1,720	518	84.0	81.0	Fair, solid, crumbly.	Creamy
	Ground once	59.4	1,740	514	84.5	79.0	do	do
	Ground 4 times	60.6	1,700	512	85.0	80.0	do	do
	Ground 10 times	60.9	1,690	516	85.5	78.0	do	do
	Ground 20 times	61.8	1,580	526	83.0	70.0	Poor, solid, crumbly.	do
Hard wheat first clear flour No. 12618.	Original material	59.4	2,000	500	74.0	86.5	Good	Light brown
	Ground once	60.0	2,040	504	78.0	87.5	do	do
	Ground 4 times	60.6	1,800	498	75.5	89.0	Very good	do
	Ground 10 times	63.5	1,740	510	74.5	86.0	Good, solid	do
	Ground 20 times	63.5	1,750	523	76.0	87.5	do	do
Hard wheat second clear flour No. 12619.	Original material	61.8	1,330	506	52.0	79.0	Fair, solid	Brown
	Ground once	62.9	1,390	514	53.5	76.0	Good, solid	do
	Ground 4 times	63.2	1,410	507	53.0	77.0	do	do
	Ground 10 times	62.9	1,360	515	54.0	79.5	Fair, solid	do
	Ground 20 times	65.0	1,350	525	51.0	79.0	Good, solid	do
RESULTS FROM STRAIGHT-DOUGH METHOD OF BAKING								
Hard wheat coarse middlings stock No. 12621.	Original material	57.9	1,870	508	93.5	92.0	Good	Light creamy
	Ground once	60.3	1,990	507	90.5	89.0	Very good	do
	Gound 4 times	65.9	1,950	526	90.0	87.0	do	do
	Ground 10 times	66.5	2,040	520	89.5	88.0	do	Creamy
	Ground 20 times	67.7	2,020	516	88.0	86.5	do	do

commercial flours ground various numbers of times

Color and condition of crust	Length of proof	Rate at which flour absorbed water	Condition of sponge	Ease with which dough mixed	Condition of dough during mixing	Condition of dough at panning	Condition of proofed loaf
	Mins.						
Brown	60						
do	64						
Brown, broken and ragged.	66						
Brown	67						
Brown, broken, and ragged.	69	Slow	Sticky	Difficult			
Slightly pale, rough.	59	Rapid		Readily		Tough	
Light brown, slightly rough.	62	do		do	Weak	Weak	Badly broken on top.
Light brown, smooth.	59						Do.
Light brown, slightly rough.	63	Slow	Sticky		Weak	Weak	
Slightly pale, smooth.	65	do	do			Sticky and weak.	Sticky and broken on top.
Pale	57		Lumpy	Difficult	Coarse and rough.	Weak, coarse, and rough.	
do	66						
Brown	66						
do	64				Weak		
do	68				do		
Light brown, slightly broken.	64	Slow	Sticky				
Brown, smooth	65	do	do				
Brown, slightly broken.	69	do	do				
Brown, smooth	65	do	do				
do	69	do	do		Dead and sticky.		
Brown, broken	60						
Brown	62						Broken on top.
Brown, broken, and specky.	62				Weak		
Pale, specky	64				Sticky and weak.		Do.
Brown	65	Slow	Sticky	Difficult	Dead and weak.	Tough	
Brown, smooth	60	do	do	do			
Brown, rough	60	do	do	do			Blistered on top.
do	56	do	do	do			
do	57	do	do	do	Dead and weak.	Tough	Do.
do	65	do	do	do	do	do	
Brown, broken, and ragged.	54	do	do	do	do	Dead and weak.	Rough and broken on top.
do	54	do	do	do	do	do	Do.
do	53	do	do	do	do	do	Do.
do	53	do	do	do	do	do	Rough and slightly broken on top.
do	53	do	do	do	do	do	Slightly broken on top.
Pale	56				Coarse and rough.	Coarse and rough.	
Brown	66						
do	67						
do	65						
do	67						

TABLE 11.—*Baking results from middlings stock and*

Kind of material used	Condition of material used	Water absorption of flour	Volume of loaf	Weight of loaf	Color of crumb	Grain of crumb	Texture of crumb	Shade of color of crumb
RESULTS FROM STRAIGHT-DOUGH METHOD OF BAKING—Con.		*P. ct.*	*C. c.*	*Gms.*	*Score*	*Score*		
Soft red winter wheat straight flour No. 12552.	Original material	58.8	2,030	501	93.0	90.5	Very good	Light creamy
	Ground once	60.6	2,160	500	94.8	93.8	do	do
	Ground 4 times	60.6	2,140	503	92.5	90.5	Good	do
	Ground 10 times	62.4	2,050	508	94.3	90.5	Very good	do
	Ground 20 times	63.8	1,940	510	93.8	89.5	Good	do
Hard wheat patent flour No. 12620.	Original material	63.2	1,820	521	84.0	86.0	Fair, solid	Creamy
	Ground once	64.4	1,850	519	85.0	85.0	Good	do
	Ground 4 times	65.0	1,720	521	85.5	89.0	Good, solid	do
	Ground 10 times	66.2	1,600	531	81.0	67.5	Poor, solid	Creamy gray
	Ground 20 times	69.1	1,560	542	82.0	68.5	do	do
Hard wheat first clear flour No. 12618.	Original material	63.2	1,980	520	73.0	86.5	Very good	Light brown
	Ground once	63.8	1,990	520	76.5	86.8	do	do
	Ground 4 times	66.5	1,990	525	77.0	86.0	do	do
	Ground 10 times	67.7	1,880	526	76.0	85.0	Good	do
	Ground 20 times	71.5	1,840	543	75.5	84.0	do	do
Hard wheat second clear flour No. 12619.	Original material	64.4	1,250	523	53.0	71.0	Fair, solid	Brown
	Ground once	67.7	1,360	534	52.5	68.0	do	do
	Ground 4 times	66.5	1,290	529	52.0	68.5	do	do
	Ground 10 times	67.7	1,280	532	52.0	68.0	do	do
	Ground 20 times	65.9	1,150	530	49.0	69.0	Poor, solid	do

NOTES.—In the absence of notations regarding sponging, mixing, panning, and proofing, it should be assumed that conditions were normal.

In making each baking test a quantity of flour equivalent to 340 grams at 13.5 per cent moisture content was used.

commercial flours ground various numbers of times—Continued

Color and condition of crust	Length of proof	Rate at which flour absorbed water	Condition of sponge	Ease with which dough mixed	Condition of dough during mixing	Condition of dough at panning	Condition of proofed loaf
	Mins.						
Pale, broken	66						Badly broken on top.
Pale, slightly broken.	69						Slightly broken on top.
Light brown, smooth.	67						
do	65						Do.
do	69					Very weak	Sticky on top.
Pale, specky on top.	60					Sticky and weak.	Sticky and slightly broken on top.
do	65					do	Sticky.
Brown, specky, and broken.	58					do	Sticky and badly broken on top.
Pale, specky on top.	63					do	Sticky and ragged on top.
do	60				Dead and weak.	do	Do.
Brown, smooth	60			Difficult	Sticky	Tough	
Brown, rough	57	Slow		do	do	do	Blistered on top.
do	56	do		do	do	do	
do	54	do		do	do	Weak	Slightly blistered on top.
do	57	do		do	Sticky and weak.	do	Blistered on top.
Brown, broken, and ragged.	49				Dead, sticky, and weak.	Dead, sticky, and weak.	Rough and broken on top.
do	51				Dead and weak.	Dead and weak.	Do.
do	47				do	do	Do.
do	49				do	do	Do.
do	48				do	Dead, sticky, and weak.	Do.

TABLE 12.—*Baking results from middlings stock*

Kind of material used	Condition of material used	Water absorption of flour	Volume of loaf	Weight of loaf	Color of crumb	Grain of crumb	Texture of crumb	Shade of color of crumb
RESULTS FROM SPONGE-DOUGH METHOD OF BAKING		*P. ct.*	*C. c.*	*Gms.*	*Score*	*Score*		
Soft red winter wheat coarse middlings stock No. 12550.	Original material	60.3	2,100	505	90.5	91.3	Very good	Light creamy
	Ground to pass through 12xx.	58.8	2,130	506	90.8	92.0	do	do
	Ground to pass through 16xx.	58.8	2,110	499	90.8	91.3	do	Light creamy gray.
	Ground to pass through 20xx.	60.0	2,170	498	90.8	91.3	do	do
	Ground to pass through 25xx.	61.5.	2,130	506	91.0	92.1	Good	do
Soft red winter wheat coarse middlings stock No. 12551.	Original material	59.7	2,090	497	93.0	91.8	Very good	Light creamy
	Ground to pass through 12xx.	60.0	2,100	493	92.8	92.9	Excellent	do
	Ground to pass through 16xx.	60.3	2,160	494	92.2	92.7	Very good	do
	Ground to pass through 20xx.	60.6	2,140	505	92.3	92.8	Excellent	do
	Ground to pass through 25xx.	60.9	2,130	500	92.3	93.2	Very good	do
Hard wheat coarse middlings stock No. 12621.	Original material	57.1	1,950	510	89.5	88.0	Fair, crumbly.	Creamy
	Ground to pass through 12xx.	60.0	1,970	508	91.0	90.0	Good	Light creamy
	Ground to pass through 16xx.	60.6	1,950	507	91.2	89.0	do	do
	Ground to pass through 20xx.	61.2	1,910	512	90.5	88.5	do	do
	Ground to pass through 25xx.	65.0	2,000	525	91.0	87.0	do	do
RESULTS FROM STRAIGHT-DOUGH METHOD OF BAKING								
Hard wheat coarse middlings stock No. 12621.	Original material	57.9	1,870	508	93.5	92.0	do	do
	Ground to pass through 12xx.	62.4	1,980	505	91.5	91.0	Very good	do
	Ground to pass through 16xx.	65.0	2,020	511	92.0	90.0	do	do
	Ground to pass through 20xx.	64.7	1,870	515	92.0	89.5	Good	do
	Ground to pass through 25xx.	67.7	1,980	527	92.5	90.0	Very good	do

NOTES.—In the absence of notations regarding sponging, mixing, panning, and proofing it should be assumed that conditions were normal.

In making each baking test a quantity of flour equivalent to 340 grams at 13.5 per cent moisture content was used.

ground to different degrees of fineness

Color and condition of crust	Length of proof	Rate at which flour absorbed water	Condition of sponge	Ease with which dough mixed	Condition of dough during mixing	Condition of dough at panning	Condition of proofed loaf
	Mins.						
Brown	60						
do	64						
do	65						
do	66						
do	64	Slow	Sticky	Difficult			
Slightly pale, rough.	59	Rapid		Readily		Tough	
do	59	Slow	Sticky				Slightly broken on top.
Slightly pale, smooth.	63	do	do				Dry and badly broken on top.
do	64	do	do				Badly broken on top.
Slightly pale, rough.	61	do	do	Difficult	Weak		Do.
Pale	57		Lumpy and crumbly.	do	Coarse and rough.	Weak, coarse, and rough.	
Brown	62						
do	63						
do	62						
do	67						
Pale	56				Coarse and rough.	Coarse and rough.	
Brown	62						
do	63						Slightly broken on top.
Pale	64					Weak	Rough on top.
Brown	64						

In factors pertaining to the mixing and handling of the dough, the excessive grinding showed some tendency to slow up the rate at which the flour absorbed water and to result in a sticky and weak dough.

The results shown here for this method of excessive grinding agree in kind with those obtained by Alsberg and Griffing in their use of the ball and flint mill, but the extent of the effect on baking quality was not nearly so marked. This leads to the conclusion that the amount of excessive grinding necessary to affect seriously the baking quality of flour material makes it unlikely that any very marked damage would occur in actual milling practice.

The baking results of the material resulting from the excessive grinding done in accordance with method No. 2 previously described, are given in Table 12. In these tests, portions of three middlings stocks were ground to various degrees of fineness. The method used in grinding and sifting each of these portions limited only the maximum size and not the minimum size of the particles of the resultant materials.

Water absorption showed a very marked tendency to increase with each increase in degree of fineness of grinding. In the case of the hard wheat middlings, the increase in absorption for the material ground to the greatest fineness over that of the original material was 7.9 per cent for the sponge-dough method of baking, and 9.8 per cent for the straight-dough method. For the two soft red winter wheat middling stocks, which were baked only by the sponge-dough method, the increases were less, being 1.2 per cent for each. Shollenberger and his coworkers in a similar investigation on hard spring wheat middlings obtained the same consistent tendency for water absorption to increase as did Alsberg and Griffing in connection with their investigation on hard spring wheat patent flour.

As might be expected, increases in the weight of loaf were shown corresponding to some extent to the increases in the percentage of water absorbed.

The volume of loaf was not materially affected by this form of excessive grinding. The differences shown are too small to be significant.

The color of crumb varied only slightly and showed no consistent tendency either to improve or to become worse. Neither did the grain of crumb show any tendencies as to direction, although in the case of this factor the variations were slightly greater. A similar lack of tendency was also apparent in the shade of color of crumb and in the color and condition of the crust.

The time required for proofing increased fairly consistently with the increase in fineness.

In factors pertaining to the mixing and handling of the dough the unground hard wheat middlings produced a coarse, rough, lumpy dough. This condition, however, was not present in connection with the doughs of the ground portions of these middlings or with the doughs of the soft red winter wheat middlings. This indicates that the coarse particles of the hard wheat middlings were somewhat more impervious to water than were the particles of which the other samples were composed, notwithstanding the fact that no slowness

was apparent in the rate at which flour absorbed water at the time of mixing. The coarseness of this material no doubt facilitated its mixing and wetting with water and to some extent compensated for the longer time required for the water to penetrate the individual particles. On the other hand the material ground to the greatest fineness did not mix so readily with the water, but the total quantity absorbed was considerably more in the end. The doughs of these finest ground materials, however, were in some instances inclined to be sticky and weak, which made them less desirable for bread-making purposes than those of coarser grinding.

The baking results obtained for this method of excessive grinding are in general agreement with those found by Shollenberger and his coworkers and by Alsberg and Griffing.

BAKING QUALITY OF THE DIFFERENT-SIZED PARTICLES OF WHICH FLOUR IS NORMALLY COMPOSED

The baking results obtained from the different sizes of particles sifted from the commercial flours and from middlings stock reduced in a normal way are presented in Table 13. The method by which this material was treated has been previously described as method No. 3.

In water absorption the coarsest siftings were generally the highest, and the finest siftings were the lowest. The exceptions to this rule occurred in the cases of the hard wheat patent and the hard wheat first clear flours. In these the siftings of intermediate fineness showed the highest water absorptions. This general tendency of the coarsest siftings to absorb the most water is the reverse of that shown in the grinding of middlings stock to different degrees of fineness and in grinding middlings stock and commercial flours various numbers of times.

In volume of loaf the siftings through the 16xx silk cloth produced the loaves of greatest volume in 8 out of 12 instances shown. The loaves of smallest volume were produced from the siftings through the 25xx silk cloth in nine instances, from the scalpings from 8xx in two instances, and from the scalpings from 12xx in one instance.

The weight of loaf was, in almost every case, greatest for the coarsest siftings and least for the finest siftings.

In color of crumb there appeared to be a consistent tendency for the finer siftings from the soft red winter wheat middlings stocks and flour to produce the best scores and the coarsest siftings the poorest scores. In the case of the siftings from the hard wheat middlings and flours no consistent tendency was apparent except that the poorest scores were obtained either from the coarsest or the finest siftings. The best grain of crumb was usually produced from the siftings of intermediate fineness and the poorest from either the coarsest or the finest siftings. On texture of crumb, size of particle had little noticeable effect. What differences were shown were generally in favor of the coarse and intermediate sized particles.

In shade of color of crumb, the lighter shades of creaminess usually occurred in connection with the intermediate siftings. The coarsest siftings usually produced the breads having the creamiest shade of color. The finest siftings tended toward grayness of crumb.

TABLE 13.—*Baking results from the various sized*

Kind of material used	Condition of material used	Proportion of whole	Water absorption of flour	Volume of loaf	Weight of loaf	Color of crumb	Grain of crumb	Texture of crumb	Shade of color of crumb
RESULTS FROM SPONGE-DOUGH METHOD OF BAKING									
Soft red winter wheat coarse middlings stock No. 12550.	Original material ground twice and sifted:	*Per cent*	*Per cent*	*C. c.*	*Gms.*	*Score*	*Score*		
	Scalpings from 8xx.	0.4	(1)	(1)	(1)	(1)	(1)	----------	----------
	Scalpings from 12xx through 8xx.	20.4	67.7	2,100	528	84.5	91.0	Very good---	Very creamy--
	Scalpings from 16xx through 12xx.	15.4	65.3	2,200	516	90.8	93.2	-----do------	Light creamy-
	Scalpings from 20xx through 16xx.	8.5	65.3	2,180	514	90.8	92.0	-----do------	-----do-------
	Scalpings from 25xx through 20xx.	17.3	60.3	2,200	500	91.5	93.7	-----do------	-----do-------
	Throughs from 25xx.	38.0	52.1	1,860	483	94.0	91.3	Good------	-----do-------
Soft red winter wheat coarse middlings stock No. 12551.	Original material ground once and sifted:								
	Scalpings from 8xx.	.9	(1)	(1)	(1)	(1)	(1)	----------	----------
	Scalpings from 12xx through 8xx.	39.4	62.6	2,150	509	91.7	90.8	Very good---	Light creamy-
	Scalpings from 16xx through 12xx.	30.7	60.3	2,170	495	92.4	91.9	-----do------	-----do-------
	Scalpings from 20xx through 16xx.	9.3	59.1	2,250	496	92.9	91.8	-----do------	-----do-------
	Scalpings from 25xx through 20xx.	9.2	56.2	2,110	488	93.4	92.3	-----do------	-----do-------
	Throughs from 25xx.	10.5	52.9	1,870	482	92.5	83.5	Fair, solid, crumbly.	White, creamy streaks.
Hard wheat coarse middlings stock No. 12621.	Original material ground once and sifted:								
	Scalpings from 8xx.	10.4	64.4	1,720	523	60.0	75.0	Poor, solid, crumbly.	Brown-------
	Scalpings from 12xx through 8xx.	36.3	59.1	1,990	505	91.3	90.0	Good, crumbly.	Light creamy-
	Scalpings from 16xx through 12xx.	21.1	60.0	1,970	510	91.5	88.5	Good------	-----do-------
	Scalpings from 20xx through 16xx.	10.3	58.8	2,080	505	91.5	85.0	Good, crumbly.	-----do-------
	Scalpings from 25xx through 20xx.	13.3	57.6	2,050	504	92.0	86.5	-----do------	-----do-------
	Throughs from 25xx.	8.6	55.3	1,860	496	85.0	65.0	Poor, solid, crumbly.	Rich creamy, gray.

[1] Insufficient quantity for baking test.

particles of which flour is normally composed

Color and condition of crust	Length of proof	Rate at which flour absorbed water	Condition of sponge	Ease with which dough mixed	Condition of dough during mixing	Condition of dough at panning	Condition of proofed loaf
	Minutes						
Brown	58	Rapid		Readily			
do	63	do		do			
do	61	do		do			
do	64	do		do			
Pale	60	Slow	Sticky	Difficult			
Brown	62	Rapid		Readily			
Brown, smooth	67	do		do			
do	64	do		do			
Slightly pale, rough.	62	Slow	Sticky		Sticky		Slightly broken on top.
Pale, rough, ragged.	59	do	do		Dead	Dead and weak.	Badly broken on top and sticky.
Light brown, ragged.	56		Lumpy and crumbly.		Weak, coarse and rough.	Weak, coarse and rough.	Slightly broken and rough on top.
Light brown	70						
do	70	Rapid		Readily			
do	72					Pliable and elastic.	
do	68					do	
Pale (dough "old").	64	Slow	Lumpy and crumbly	Difficult	Sticky and weak.	Soft and sticky.	Slightly broken and sticky on top.

TABLE 13.—*Baking results from the various sized*

Kind of material used	Condition of material used	Proportion of whole	Water absorption of flour	Volume of loaf	Weight of loaf	Color of crumb	Grain of crumb	Texture of crumb	Shade of color of crumb
RESULTS FROM SPONGE-DOUGH METHOD OF BAKING—con.									
Soft red winter wheat straight flour No. 12552.	Siftings from original material:	*Per cent*	*Per cent*	*Gms.*	*C. c.*	*Score*	*Score*		
	Scalpings from 12xx.	10.7	61.8	2,220	502	93.5	92.0	Excellent	Light creamy.
	Scalpings from 16xx through 12xx.	58.1	60.3	2,230	490	93.3	92.5	do	do.
	Scalpings from 20xx through 16xx.	6.4	59.1	2,220	486	93.4	93.0	Very good	do.
	Scalpings from 25xx through 20xx.	7.9	57.1	2,090	488	94.0	91.0	Good	do.
	Throughs from 25xx.	16.9	54.7	1,920	483	93.5	86.5	Fair, solid, crumbly.	do.
Hard wheat patent flour No. 12620.	Siftings from original material:								
	Scalpings from 12xx.	14.0	60.3	1,860	514	89.5	89.0	Good	do.
	Scalpings from 16xx through 12xx.	49.6	60.3	1,880	514	85.8	87.5	do	Creamy.
	Scalpings from 20xx through 16xx.	9.0	60.9	1,910	513	85.0	87.0	do	do.
	Scalpings from 25xx through 20xx.	7.0	60.0	1,780	511	82.5	75.0	Fair, solid	do.
	Throughs from 25xx.	20.4	57.9	1,650	498	82.0	65.0	Very poor, solid, crumbly.	Creamy gray.
Hard wheat first clear flour No. 12618.	Siftings from original material:								
	Scalpings from 8xx.	Tr.	(1)	(1)	(1)	(1)	(1)		
	Scalpings from 12xx through 8xx.	15.6	60.0	1,990	510	76.5	86.5	Good, crumbly.	Light brown.
	Scalpings from 16xx through 12xx.	20.5	61.5	2,040	517	78.5	87.0	Very good	do.
	Scalpings from 20xx through 16xx.	15.2	61.5	2,090	517	79.0	88.5	do	do.
	Scalpings from 25xx through 20xx.	14.3	62.4	1,960	511	78.0	86.0	Good	do.
	Throughs from 25xx.	34.4	58.5	1,880	503	75.0	84.0	do	do.
Hard wheat second clear flour No. 12619.	Siftings from original material:								
	Scalpings from 8xx.	Tr.	(1)	(1)	(1)	(1)	(1)		
	Scalpings from 12xx through 8xx.	9.7	65.6	1,220	535	45.0	65.0	Poor, solid	Brown.
	Scalpings from 16xx through 12xx.	60.2	60.9	1,390	514	54.5	73.5	Fair, solid	do.
	Scalpings from 20xx through 16xx.	6.7	61.2	1,440	510	53.5	72.5	Good, solid	do.
	Scalpings from 25xx through 20xx.	10.4	60.3	1,430	506	53.0	75.0	do	do.
	Throughs from 25xx.	13.0	57.4	1,320	500	52.5	70.0	Fair, solid	do.

[1] Insufficient quantity for baking test.

particles of which flour is normally composed—Continued

Color and condition of crust	Length of proof	Rate at which flour absorbed water	Condition of sponge	Ease with which dough mixed	Condition of dough during mixing	Condition of dough at planning	Condition of proofed loaf
	Minutes						
Brown, slightly broken.	60	Rapid	-------	Readily---	Tough------	----------	Slightly broken on top.
Brown, smooth-	65	---do---	-------	---do------	----------	Tough------	
Brown, slightly broken.	61	---do---	-------	---do------	----------	Sticky------	
Light brown broken.	63	Slow--	Sticky-	----------	----------	----------	Do.
Pale, badly broken.	63	---do---	---do---	----------	Dead, weak and sticky.	Sticky------	Broken and ragged on top.
Pale, specky----	60	Rapid	-------	Readily---	Coarse and rough.	----------	Slightly broken on top.
Brown, specky--	61	-------	-------	----------	----------	----------	
-----do---------	62	-------	-------	----------	----------	----------	
-----do---------	62	Slow--	Sticky	Difficult--	Sticky------	----------	
-----do---------	61	---do---	---do---	---do------	Dead, weak and sticky.	Dead, weak and sticky.	
----------	------	-------	-------	----------	----------	----------	
Brown, smooth-	63	-------	-------	----------	----------	----------	
-----do---------	65	Rapid	-------	Readily---	Slightly weak	----------	
-----do---------	61	---do---	-------	---do------	----------	----------	Blistered on top.
-----do---------	52	---do---	-------	---do------	----------	----------	
Brown, rough---	60	Slow--	Sticky-	Difficult--	Dead and weak.	Weak------	Blistered and sticky on top.
----------	------	-------	-------	----------	----------	----------	
Brown, broken, ragged.	54	-------	-------	----------	Dead and weak.	Dead, tough and weak.	Rough and porous on top
-----do---------	52	Slow--	Sticky-	Difficult--	-----do------	-----do------	Rough and slightly broken on top.
-----do---------	47	---do---	---do---	---do------	-----do------	Dead and sticky.	Do.
-----do---------	47	---do---	---do---	---do------	-----do------	-----do------	Rough and porous on top.
-----do---------	51	---do---	---do---	---do------	Dead and sticky.	Dead, tough and sticky.	Rough and slightly broken on top.

TABLE 13.—*Baking results from the various sized*

Kind of material used	Condition of material used	Proportion of whole	Water absorption of flour	Volume of loaf	Weight of loaf	Color of crumb	Grain of crumb	Texture of crumb	Shade of color of crumb
RESULTS FROM STRAIGHT-DOUGH METHOD OF BAKING									
Hard wheat coarse middlings stock No. 12621.	Original material ground once and sifted:	*Per cent*	*Per cent*	*C. c.*	*Gms.*	*Score*	*Score*		
	Scalpings from 8xx.	10.4	67.7	1,650	527	65.0	77.0	Poor, solid, crumbly.	Brown
	Scalpings from 12xx through 8xx.	36.3	62.6	1,930	510	92.0	91.0	Good	Light creamy.
	Scalpings from 16xx through 12xx.	21.1	61.8	2,090	510	93.0	92.0	do	do
	Scalpings from 20xx through 16xx.	10.3	61.2	2,060	510	92.0	91.0	do	do
	Scalpings from 25xx through 20xx.	13.3	61.8	2,090	511	91.5	88.0	Very good	do
	Throughs from 25xx.	8.6	59.4	1,920	505	88.0	85.0	Fair	Rich creamy gray.
Soft red winter wheat straight flour No. 12552.	Siftings from original material:								
	Scalpings from 12xx.	10.7	63.5	2,100	513	92.5	90.0	Good	Light creamy.
	Scalpings from 16xx through 12xx.	58.1	64.4	2,280	505	92.7	91.5	Very good	do
	Scalpings from 20xx through 16xx.	6.4	60.9	2,200	500	93.8	91.0	do	do
	Scalpings from 25xx through 20xx.	7.9	59.4	2,180	493	93.8	90.0	do	do
	Throughs from 25xx.	16.9	56.5	1,880	490	94.3	85.5	Fair	do
Hard wheat patent flour No. 12620.	Siftings from original material:								
	Scalpings from 12xx.	14.0	63.5	1,880	514	88.0	91.5	Good	do
	Scalpings from 16xx through 12xx.	49.6	64.7	1,780	520	86.5	89.5	Very good	Creamy
	Scalpings from 20xx through 16xx.	9.0	65.3	1,990	523	84.5	87.5	Good	do
	Scalpings from 25xx through 20xx.	7.0	(1)	(1)	(1)	(1)	(1)		
	Throughs from 25xx.	20.4	64.4	1,640	513	82.5	67.5	Poor, solid	Creamy gray
Hard wheat first clear flour No. 12618.	Siftings from original material:								
	Scalpings from 8xx.	Tr.	(2)	(2)	(2)	(2)	(2)		
	Scalpings from 12xx through 8xx.	15.6	66.2	2,010	528	77.5	86.5	Very good	Light brown
	Scalpings from 16xx through 12xx.	20.5	66.2	2,080	525	77.5	85.5	do	do
	Scalpings from 20xx through 16xx.	15.2	67.1	2,140	526	77.0	84.0	Good	do
	Scalpings from 25xx through 20xx.	14.3	66.2	2,130	521	79.0	87.0	Very good	do
	Throughs from 25xx.	34.4	64.7	1,940	523	71.0	78.0	Good	Brown

[1] Not baked.
[2] Insufficient quantity for baking test.

particles of which flour is normally composed—Continued

Color and condition of crust	Length of proof	Rate at which flour absorbed water	Condition of sponge	Ease with which dough mixed	Condition of dough during mixing	Condition of dough at panning	Condition of proofed loaf
	Minutes						
Light brown, ragged.	45				Weak, coarse and rough.	Weak, coarse and rough.	Rough on top.
Pale	64						Slightly broken on top.
do	70						
Light brown	65						Do.
do	67						Do.
Pale	63						
Light brown, smooth.	64				Tough		
do	72						
Brown, smooth	69						
Slightly pale and broken.	68				Weak		
do	64				Dead, weak	Weak, sticky and pliable.	Sticky and badly broken on top.
Pale, specky, broken.	65				Coarse and rough.	Weak	Slightly broken on top.
Brown, broken	60					do	Badly broken on top.
Brown, slightly broken.	64						
Brown, specky	61				Dead and weak.	Weak and sticky.	Slightly broken on top.
Brown, rough	60					Weak	
do	60					do	
do	57					do	
do	55						
do	56					Weak	Broken on top.

TABLE 13.—*Baking results from the various sized*

Kind of material used	Condition of material used	Proportion of whole	Water absorption of flour	Volume of loaf	Weight of loaf	Color of crumb	Grain of crumb	Texture of crumb	Shade of color of crumb
RESULTS FROM STRAIGHT-DOUGH METHOD OF BAKING—Continued.									
	Siftings from original material:	*Per cent*	*Per cent*	*C. c.*	*Gms.*	*Score*	*Score*		
	Scalpings from 8xx.	.1	(1)	(1)	(1)	(1)	(1)	----------	----------
	Scalpings from 12xx through 8xx.	9.7	70.3	1,260	548	44.0	66.0	Poor, solid	Brown
Hard wheat second clear flour No. 12619.	Scalpings from 16xx through 12xx.	60.2	65.9	1,270	523	52.0	66.5	do	do
	Scalpings from 20xx through 16xx.	6.7	65.0	1,380	526	52.5	63.0	Fair, solid	do
	Scalpings from 25xx through 20xx.	10.4	62.6	1,280	518	51.5	65.0	Poor, solid	do
	Throughs from 25xx.	13.0	62.4	1,150	512	42.5	55.0	Very poor, solid.	do

[1] Insufficient quantity for baking test.

NOTES.—In the absence of notations regarding sponging, mixing, panning, and proofing it should be assumed that conditions were normal.

In making each baking test a quantity of flour equivalent to 340 grams at 13.5 per cent moisture content was used.

particles of which flour is normally composed—Continued

Color and condition of crust	Length of proof	Rate at which flour absorbed water	Condition of sponge	Ease with which dough mixed	Condition of dough during mixing	Condition of dough at panning	Condition of proofed loaf
	Minutes						
Brown, broken, ragged.	48				Dead, coarse and rough.	Dead, sticky and weak.	Broken and rough on top.
do	48				Dead and sticky.	do	Do.
do	48				do	do	Do.
do	48				do	do	Do.
Brown, badly broken, ragged.	48				do	Sticky and weak.	Badly broken and rough on top.

The siftings of intermediate fineness produced, as a general rule, the bread of the brownest and smoothest crust. The crust of the bread from the finest siftings usually tended toward paleness and roughness.

The siftings requiring the longest proofing time in the pan were of intermediate fineness. The fine siftings absorbed water more slowly than did those of intermediate or coarse granulation and usually produced a sticky sponge. These finer siftings also showed other indications of inferiority as a bread flour over the coarse and intermediate siftings, such as a dead and weak dough during mixing and at the time of panning and a broken and ragged top on the proofed loaf.

The findings in connection with this form of treatment are in general agreement with those of Le Clerc and his coworkers.

SUMMARY

The results obtained from these investigations do not differ in any marked way from those of previous investigations. They do, however, shed light on certain phases of the subject on which no information was previously available, and they clarify and strengthen certain conclusions of previous investigations.

The results obtained were similar for the two methods of excessive grinding employed. They indicate that the chemical composition and baking quality of flour may be affected by excessive grinding. In noting the effect produced, however, full consideration should be given to the excessiveness of the grinding required to produce this effect, otherwise improper importance may be attached to it. Study of the results in this light indicates that such a considerable amount of excessive grinding was required to bring about any appreciable effect in most of the factors examined that it is very improbable that any very marked change in the flour, except in its fineness and whiteness, would occur under commercial conditions unless all, or nearly all, of the milling reductions were accomplished under excessive roll pressure. Even then there is some doubt as to whether the degree of effect would be appreciable enough to make any material difference in bread-baking quality.

In the preceding pages it has been definitely shown that, as a result of grinding flour excessively, certain chemical changes take place that alter the quality of the gluten proteins, and change the physical condition of the starch granules. The extent of these changes is variable and depends somewhat upon the class of flour under consideration.

In baking results, the most marked effect from excessive grinding was the increase in water absorption and the deterioration in color of crumb. As for the other baking factors, the effect was more or less variable in degree and somewhat inconsistent as to tendency, but usually when any marked change occurred it was in those samples which were most excessively ground.

With respect to the various sizes of particles of which flour is normally composed the differences noted in chemical composition and baking results, because of their more practical application to ordinary milling practice, are of greater importance than those noted in connection with excessive grinding. The smaller-sized particles—

those passing through 20xx and 25xx sieves—were found to contain less protein and wet and dry gluten, than the coarser particles. The quality of the gluten was likewise poorer in the smaller-sized separates.

With the soft red winter wheat materials the smaller-sized particles were characterized by low ash contents. The reverse of this was true of the separates sieved from the hard wheat materials. The active acidity of the separates of all sizes was practically the same.

The smaller-sized particles usually contained the least amount of gasoline soluble pigments.

In regard to the baking quality of the various-sized particles of which flour is normally composed the particles of intermediate size gave the best appearing loaf of bread. The flour particles sifted through the 20xx and 25xx sieves in many instances acted weakly in the doughing and proofing and produced a loaf of inferior quality. It therefore follows that if these fine particles were separated from flour as ordinarily milled the bread-baking qualities of the remaining flour would be improved. This would not be advisable, however, unless the resultant flours could be marketed at a net gain to the miller. It is probable that some day the miller may find it to his advantage to do something of this sort as it is possible that the fine particles may be of particular value for some other purpose than bread making. This statement is induced by results obtained from some pastry experiments conducted in connection with these investigations, in which it was found that these fine flour particles produced a very satisfactory pie crust with the use of considerably less shortening than was required by the coarser flour particles. This latter fact is due, no doubt, to the lower quantity and inferior quality of the gluten contained in the flour particles of finest size.

EXCESSIVE GRINDING

The more excessively the materials were ground the whiter they became and the more difficult it was to bolt them.

Excessive grinding reduced the moisture content of the materials but did not affect their crude protein and ash contents.

A tendency was shown for the color pigments extractable in gasoline to be increased where grinding was very excessive. A definite but not considerable tendency was shown for the hydrogen-ion concentration to increase with excessive grinding.

For the particular form of excessive grinding employed in which the materials were ground various numbers of times a gradual decrease in the wet and dry gluten content of the soft red winter wheat middlings seemed to have taken place. No decrease in quantity or quality of gluten was experienced in the hard wheat middlings or in the first clear flour. In the soft red winter wheat straight and the hard wheat patent flours only the samples ground twenty times showed any injury to the gluten.

In the samples ground to a definite degree of fineness the results obtained for gluten quantity and quality were similar to those obtained from the samples ground various numbers of times.

The viscosity measurements for gluten quality bear out in a general way the findings obtained for the washed gluten tests. The glutenin content was not altered to any noticeable extent. Only in the soft red winter wheat straight flour was there any reduction in the percentage of water soluble nitrogen, and in only one or two instances did there appear to be any increase in the protein content of the gluten proteins.

The diastatic activity of the resultant flours was materially increased by excessive grinding.

In the baking tests conducted on the middlings stock and flour treated to excessive grinding the results for water absorption showed a very marked and consistent tendency to increase. Increases in weight of loaf corresponding fairly closely to the increases in water absorption also were shown.

The size of the loaf showed a slight tendency to decrease with the increase in the number of times of grinding. On the other hand, in grinding to a definite degree of fineness the only tendency apparent was that the greatest volumes resulted from the materials of intermediate fineness.

The effect of the number of grindings on color and grain of crumb was that the best scores were mostly from the original materials or the portions ground only once, and the poorest scores from the portions ground twenty times. This tendency was not apparent for these factors when the form of excessive grinding used was that of grinding to a definite degree of fineness. The general appearance and texture of crumb were little affected and indicated no very pronounced tendencies as to direction.

In such factors as pertain to the mixing and handling of the dough excessive grinding showed some tendency to slow up the rate at which flour absorbed water, to increase the time required for proofing, and to result in a sticky and weak dough.

DIFFERENT-SIZED PARTICLES OF WHICH FLOUR IS NORMALLY COMPOSED

With respect to the different sizes of particles of which flour is normally composed, the ash content of the particles of the soft red winter wheat flours were, in most instances, progressively lower as the size of the particle decreased. The reverse of this was the case with the hard wheat flours. The protein content of the finer flour particles passing through the 25xx sieve was considerably lower than that of the coarser sizes, as was also the quantity and quality of the gluten.

In general, a fairly close parallelism existed between titratable acidity and ash content. In hydrogen-ion concentration there was no appreciable difference for the various sizes of flour particles.

The finest flour particles were whitest in color according to the gasoline test. This also was true with respect to appearance.

As in the case of protein content the finest particles contained the least percentage of wet and dry gluten, but if the quality of gluten is judged from the standpoint of the water absorbed per gram of dry gluten the quality factors seem to have been fairly constant for all sizes of particles.

The diastatic activity of the different-sized particles varied in tendency but was fairly consistent in that the flours which passed

through the 16xx, 20xx, and 25xx sieves were noticeably greater in diastatic power than were those passing through the 8xx and 12xx sieves.

In the baking results obtained from the different sizes of particles sifted from commercial flours and from middlings stock reduced in a normal way the water absorption for the coarsest siftings was generally highest and for the finest siftings lowest. This general tendency of the coarsest siftings to absorb the most water is the reverse of that shown in the case of the middlings stock and flours treated to excessive grinding.

In volume of loaf the siftings through the 16xx silk cloth produced the loaves of greatest volume in 8 out of 12 instances. The loaves of smallest volume were produced from the siftings through 25xx silk cloth in 11 out of 12 instances.

The weight of loaf was, in almost every case, greatest for the coarsest siftings and least for the finest siftings.

In color of crumb there appeared in the case of the soft red winter wheat materials to be some tendency for the finer siftings to produce the best scores and the coarsest siftings the poorest scores. The best grain of crumb was usually produced from the siftings of intermediate fineness. The siftings giving the best texture of crumb were the coarse and intermediate sizes. The creamiest shades of color of crumb were usually from the coarsest siftings.

The siftings of intermediate fineness produced, as a general rule, the bread of the brownest and smoothest crust and required the longest proofing time. The finer siftings absorbed water more slowly than did those of intermediate or coarse granulation, and usually produced a sticky sponge. These finer siftings also showed other indications of inferiority as a bread flour over the coarse and intermediate siftings, such as a dead and weak dough during mixing and at the time of panning and a broken and ragged top on the proofed loaf.

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